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Strong air-water interaction phenomena during breaking events generated by modulational instabilit

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Direct Numerical Simulation (DNS) of the Navier-Stokes equations for a two-phase flow (water and air) is here adopted to study the dynamics of the modulational instability of free surface waves. The study is focused on the role played by the modulational instability, and by the breaking process in particular, on the interaction between ocean and atmosphere.

If the initial steepness of the fundamental wave component exceeds a threshold value, breaking occurs which causes the air flow to separate from the crest. This generates a strong vorticity structure in air, which interacts with the free surface and leads to the formation of a secondary vorticity structure of opposite sign. The dipolar structures formed by the primary and secondary vortices propagate upwards, significantly enhancing the vertical transfer of momentum. It is worth noticing that such strong vorticity structures only appear in presence of breaking whereas nothing happens if the modulational process does not reach the breaking point.

Due to the periodicity of the modulational process, the formation of dipoles is recurrent with the period associated to the group. A train of dipoles is released in the atmosphere, with important effects on the water-to-air energy transfer and on the vertical transfer of horizontal momentum. Although not investigated in this study, there are other important consequences in terms of exchange of aerosols, chemicals and gases.